

Achene Microstructure in *Pycreus*, *Gahnia* and *Schoenus* (Cyperaceae) from China and Their Taxonomic Significance

Jian-Qiu LIU^a and Su-Juan LIN^b

^aBioengineering College, Fujian Normal University, Fuzhou, 350007 CHINA;

^bFaculty of Science, Rikkyo University, Nishi-ikebukuro 3-34-1, Toshima-ku, Tokyo, 171-8501 JAPAN

(Received on November 24, 1998)

The achenes of 15 species in three genera, 10 species of *Pycreus*, 3 of *Gahnia* and 2 of *Schoenus*, in China were observed morphologically using stereoscope and scanning electron microscope. There are some differences among the genera in the characters such as achene shape, color, size and presence of beak. These characters are, therefore, of certain value of classification into genera. Acid treated achenes with their cuticle and outer periclinal cell walls removed were observed by SEM, and all of them in 15 species could be divided into four types in microstructure. 1) Reticulate-tuberculate. In this type the achenes have a reticulate anticlinal wall and a single tuberculate protuberance in center of tangential cell wall. 2) Striate. There are striae thickened on achenes surface, but the cell shape is unclear. 3) Reticulate. Fruit coat has a reticulate anticlinal wall. 4) Tuberculate. Achene surface sculpture is tuberculate. The results revealed that there were interspecific differences in the achene-coat ornamentation, and the specific characters of the achenes were recognized in 15 species observed here.

Key words: Achene, ornamentation, *Pycreus*, *Gahnia*, *Schoenus*

Introduction

About 29 genera and more than six hundred species were recorded in Chinese Cyperaceae. The taxonomy of sedges is difficult, because of the reduced structure of flowers and the simplified vegetative characters. The microstructure of achene is diverse in genera but consistent for species (Tucker and Norton 1990). Six genera and 75 species in China have been observed by Liu (1992, 1993), Liu and Huang (1993), and Liu et al. (1993, 1995), and it was suggested that the microstructure combined with achene shape and size can be diagnostic in distinguishing genera and even species in this family.

The present study examined microstruc-

ture of achenes of *Pycreus*, *Gahnia* and *Schoenus* including 15 species in the Cyperaceae from China by SEM. It is expected that the achene microstructure can provide new evidence for the systematical classification of the Cyperaceae.

Materials and Methods

Materials used in this study were obtained from specimens deposited in the Herbarium of Institute of Botany Academia Sinica (PE) or the Bioengineering College Herbarium of Fujian Normal University (FNU). Ten species of *Pycreus*, three of *Gahnia* and two of *Schoenus* in China were examined under SEM. The collectors and the localities where the materials were obtained are shown

in Table 1. Achenes were submerged in acetoxylic acid (9 parts acetic anhydride: 1 part concentrated sulfuric acid) solution at room temperature for 5 minutes, and washed with glacial acetic acid, and then were treated in 70 % alcohol by ultrasonic cleaner to remove the cuticle and outer periclinal wall of epidermis. The cleaned achenes were air dried and fixed on aluminum stub. A7 Å coating of gold-palladium was applied in a sputter coater. Coated achenes were then examined and photographed with Hitachi S-570 scanning electron microscope. Ten achenes were observed for each species to take their average for data.

Results

Achenes of the genera examined are generally narrowly to broadly obovoid, oblong-ovoid or ellipsoidal in shape. Achenes of *Pycreus* are 0.57–1.27 mm in length and 0.34–0.98 mm in width, two-sides convex. The larger fruits were observed in *Gahnia*, which commonly reach 2.50–3.85 mm × 1.10–2.05 mm in size, and trigonous in

Gahnia and *Schoenus*. Mature achenes are brown to dark brown in color. The beak is persistent in *Pycreus* species (except for *P. sulcinux* and *P. pseudo-latespicatus*), but absent or invisible in *Gahnia* and *Schoenus*.

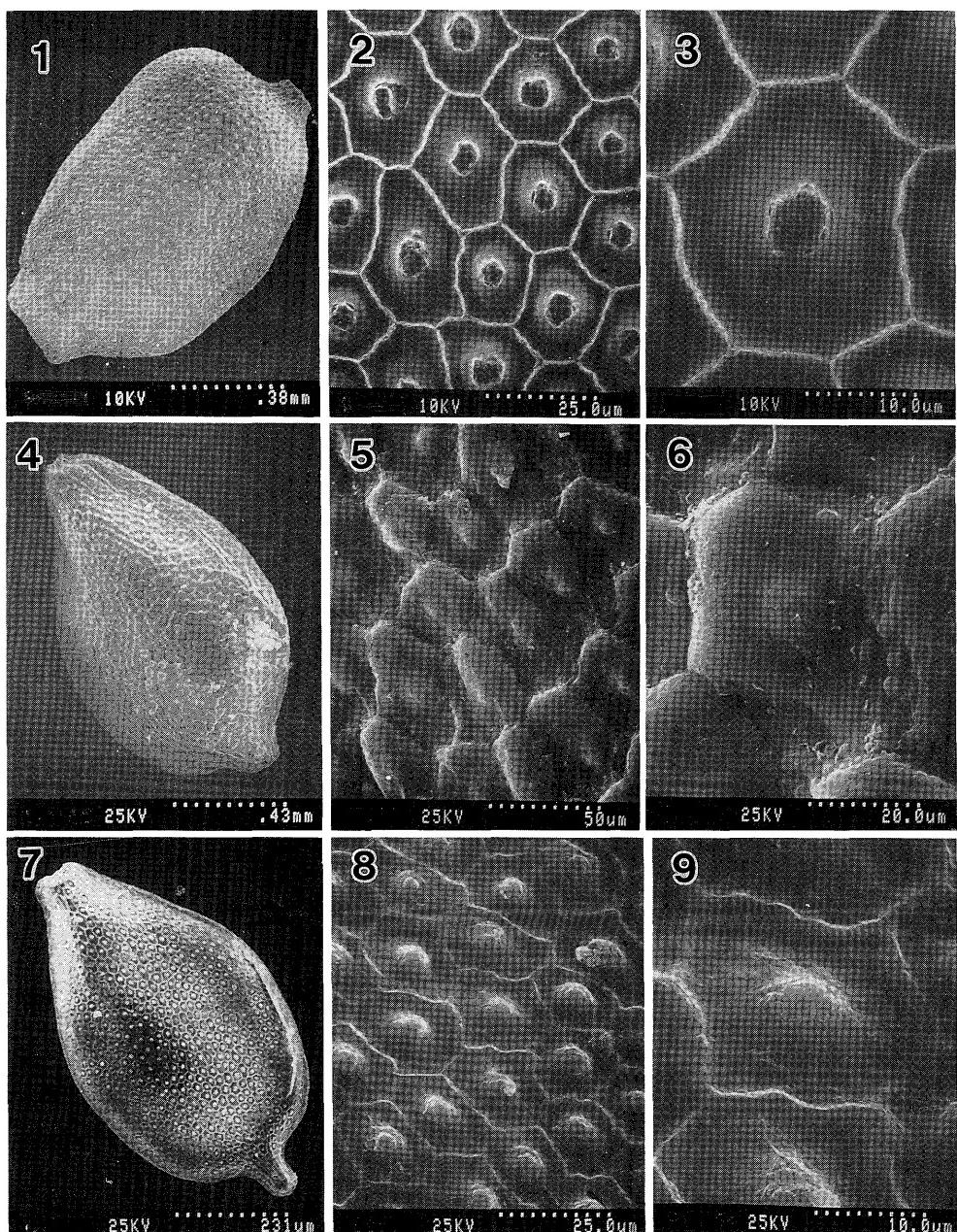
Based on the differences in ornamentation and micromorphological characters observed, the four sculpture types of achenes were recognized in the three genera.

1. Reticulate-tuberculate. In this type, anticlinal walls show reticulate structure on the surface of achene and a single tuberculate protuberance in lumina of tangential cell walls, which characterizes most *Pycreus* species (Figs. 1–24). In a few as in *Gahnia* (Figs. 31–39), nodules are present on the protuberance. Usually cellular lumens are hexagonal, narrowly hexagonal or irregularly polygonal. The boundary can be thick as in *G. javanica* (Fig. 36) or thin as in *P. polystachyus* (Fig. 18). The tangential walls are smooth (*P. polystachyus*, Fig. 18) or minutely roughened (*P. globosus*, Fig. 9). The anticlinal walls are straight in most of the species as in *P. lijiangensis* (Fig. 12) or

Table 1. Source of achene materials used in this study

Taxa	Localities and specimen number	Herbarium
<i>Pycreus delavayi</i> C.B.Clarke	Ninghua, Fujian, 0423	PE
<i>P. unioloides</i> (R.Br.) Urb.	Kunming, Yunnan, 0180	PE
<i>P. globosus</i> (All.) Reichb.	Haerbin, Heilongjiang, 296239	PE
<i>P. lijiangensis</i> L.	Lijiang, Yunnan, 65044	PE
<i>P. sulcinux</i> (C.B.Clarke) C.B.Clarke	Simao, Yunnam, 05820	PE
<i>P. polystachyus</i> (Rottb.) P. Beauv.	Changle, Fujian, 1364	FNU
<i>P. pumilus</i> (L.) Domin	Yunxiao, Fujian, 100	FNU
<i>P. sanguinolentus</i> (Vahl) Nees	Dedu, Heilongjiang, 10884	PE
<i>P. pseudo-latespicatus</i> L.K.Dai	Guizhou, 508768	PE
<i>P. diaphanus</i> (Schrad) Tang et Wang	Lijiang, Yunnan	PE
<i>Gahnia tristis</i> Nees	Zhaoan, Fujian, 52	FNU
<i>G. javanica</i> Moritz	Yangshan, Guangdong, 1309	PE
<i>G. bariensis</i> Benl	Wuyishan, Fujian, 800712	PE
<i>Schoenus calostachyus</i> (R.Br.) Poir	Guangdong, 11415	PE
<i>S. nudifructus</i> C.Chen	Kunming, Yunnan, 16507	PE

PE: Herbarium of Beijing Botanical Institute; FUN: Herbarium of Fujian Normal University.



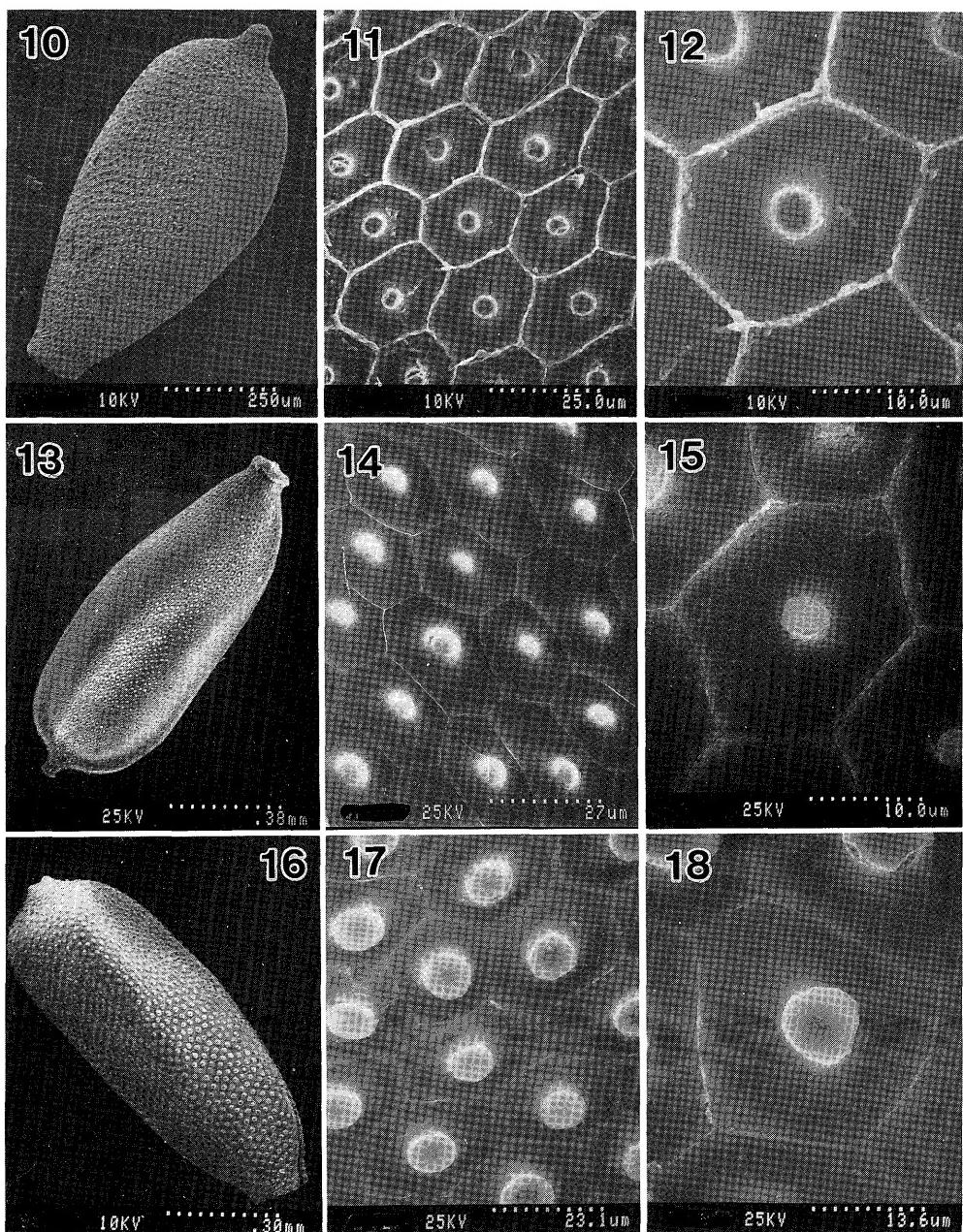
Figs. 1-9. Shape and microstructure of achenes in *Pycreus* (Cyperaceae) from China. 1-3. *Pycreus delavayi*. 4-6. *P. unioloides*. 7-9. *P. globosus*.

slightly undulate as in *P. sanguinolentus* (Fig. 24).

2. Striate. Fruit surface has densely longitudinal striate thickenings, cell shape unclear, only one species (*P. pseudolatespici*

catus, Fig. 30).

3. Reticulate. In this type the achenes have a reticulate anticlinal wall. The tangential wall surface may be depressed in center as in *S. nudifructus* (Figs. 43-45), or



Figs. 10–18. Shape and microstructure of achenes in *Pycreus* (Cyperaceae) from China. 10–12. *P. lijiangensis*. 13–15. *P. sulcinux*. 16–18. *P. polystachyus*.

covered with densely granulate as in *P. diaphanus* (Figs. 26, 27), cell cavities are irregularly tetra- to hexagonal or narrowly hexagonal (Figs. 26, 27).

4. Tuberculate. The achene surface ap-

pears irregularly hexagonal or nearly ovoid tuberculate protuberance structure. This type was observed only in *S. calostachyus* (Figs. 40–42).

The following is a brief comparative de-

scription of each species. The species are enumerated in order of the system by Tan and Wang (1961).

1. *Pycreus delavayi* C.B.Clarke (Figs. 1, 2, 3)

Achenes obovoid or narrowly obovoid, two-sides convex with beak, blackish. 0.86–0.95 mm × 0.65–0.75 mm in size; the sculpture of achenes reticulate-tuberculate, cell lumens polygonal or irregularly oblong, anticlinal walls straight or slight sinuous, internal tangential walls of cell smooth or slightly convex with one tuberculate protuberance that ca. 6–7 µm in diameter and have a few granules at the apex.

2. *Pycreus unioloides* (R.Br.) Urb. (Figs. 4, 5, 6)

Achenes obovoid, two-sides convex with short beak, brown or dark, 1.35–1.46 mm × 0.82–0.91 mm in size; irregularly reticulate-tuberculate in microstructure, cell shape unclear, anticlinal walls concave, internal tangential walls of cell roughed uneven, with one tuberculate protuberance in center.

3. *Pycreus globosus* (All.) Reichb. (Figs. 7, 8, 9)

Achenes oblong or ellipsoidal, two-sides convex with beak, brown, 0.70–0.80 × 0.42–0.50 mm in size; achene sculpture reticulate-tuberculate, cell lumens irregularly hexagonal or polygonal, anticlinal walls straight or slight sinuous, internal tangential cell walls slightly convex with one tuberculate protuberance which have a few granulate satellites at the apex, protuberance ca. 6–8 µm in diameter.

Based on the comparison in the microstructure of achenes of varieties in the *P. globosus*, no useful differences were recognized between varieties *P. globosus* var. *globosus* and *P. globosus* var. *minimus*.

4. *Pycreus lijangensis* L.K.Dai (Figs. 10, 11, 12)

Achenes oblong or narrowly obovoid, one side flat and another convex with short beak at the apex, brownish, 0.72–0.86 mm

× 0.35–0.40 mm in size; the microstructure of achenes reticulate-tuberculate, cell lumens hexagonal, anticlinal walls linear, straight, internal tangential cell walls smooth, with one tuberculate protuberance which constricted in the base, protuberance ca. 4–5 µm in diameter, granulate satellites absent.

5. *Pycreus sulcinux* (C.B.Clarke) C.B.Clarke (Figs. 13, 14, 15)

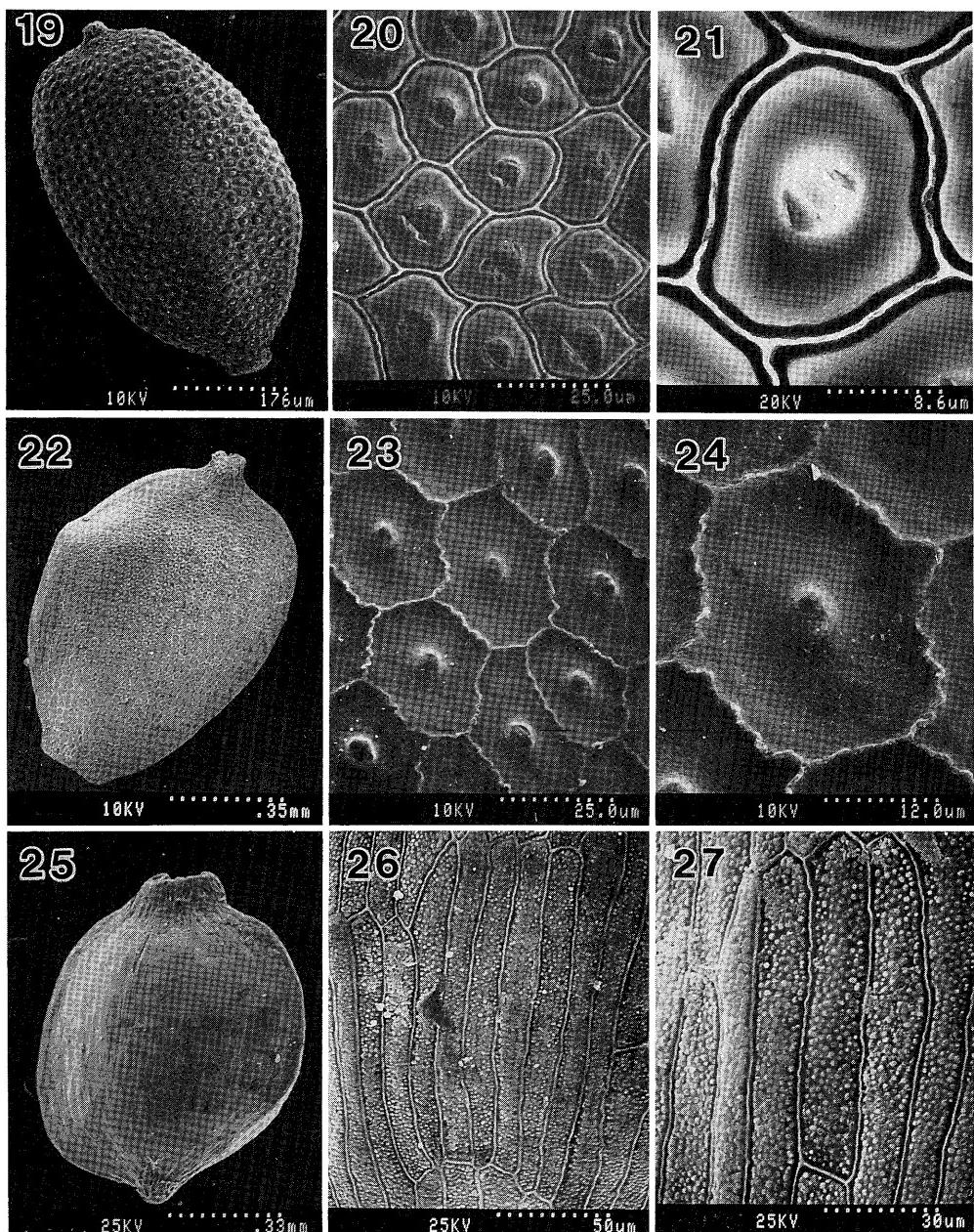
Achenes oblong, two-sides convex, beak a low boss, brownish, 1.18–1.27 mm × 0.42–0.48 mm in size; sculpture of achenes reticulate-tuberculate type, cell lumens hexagonal or nearly hexagonal, anticlinal walls linear, straight, internal tangential cell walls smooth with one tuberculate protuberance that constricted in the base, protuberance smooth ca. 3–4 µm in diameter, satellites absent.

6. *Pycreus polystachyus* (Rottb) P.Beauv. (Figs. 16, 17, 18)

Achenes oblong or nearly ellipsoidal two-sides convex, beak inconspicuous, brownish, 0.90–0.96 mm × 0.46–0.53 mm in size; sculpture of achenes reticulate-tuberculate, cell lumens hexagonal or nearly hexagonal, anticlinal walls thin, straight, internal tangential cell walls smooth, slightly convex in center, with one tuberculate protuberance that constricted in the base, protuberance smooth, ca. 9–10 µm in diameter, without satellites.

7. *Pycreus pumilus* (L.) Domin (Figs. 19, 20, 21)

Achenes ovoid or nearly ovoid, two-sides convex, with beak at the apex, brown, 0.57–0.63 mm × 0.34–0.39 mm in size; achene sculpture reticulate-tuberculate, cell lumens hexagonal or irregularly hexagonal, anticlinal walls straight or slightly sinuous, internal tangential anticlinal cell walls smooth and concave along the margin, with one tuberculate protuberance in the center, protuberance smooth, and constricted in the base, ca. 6–8 µm in diameter, satellites ab-



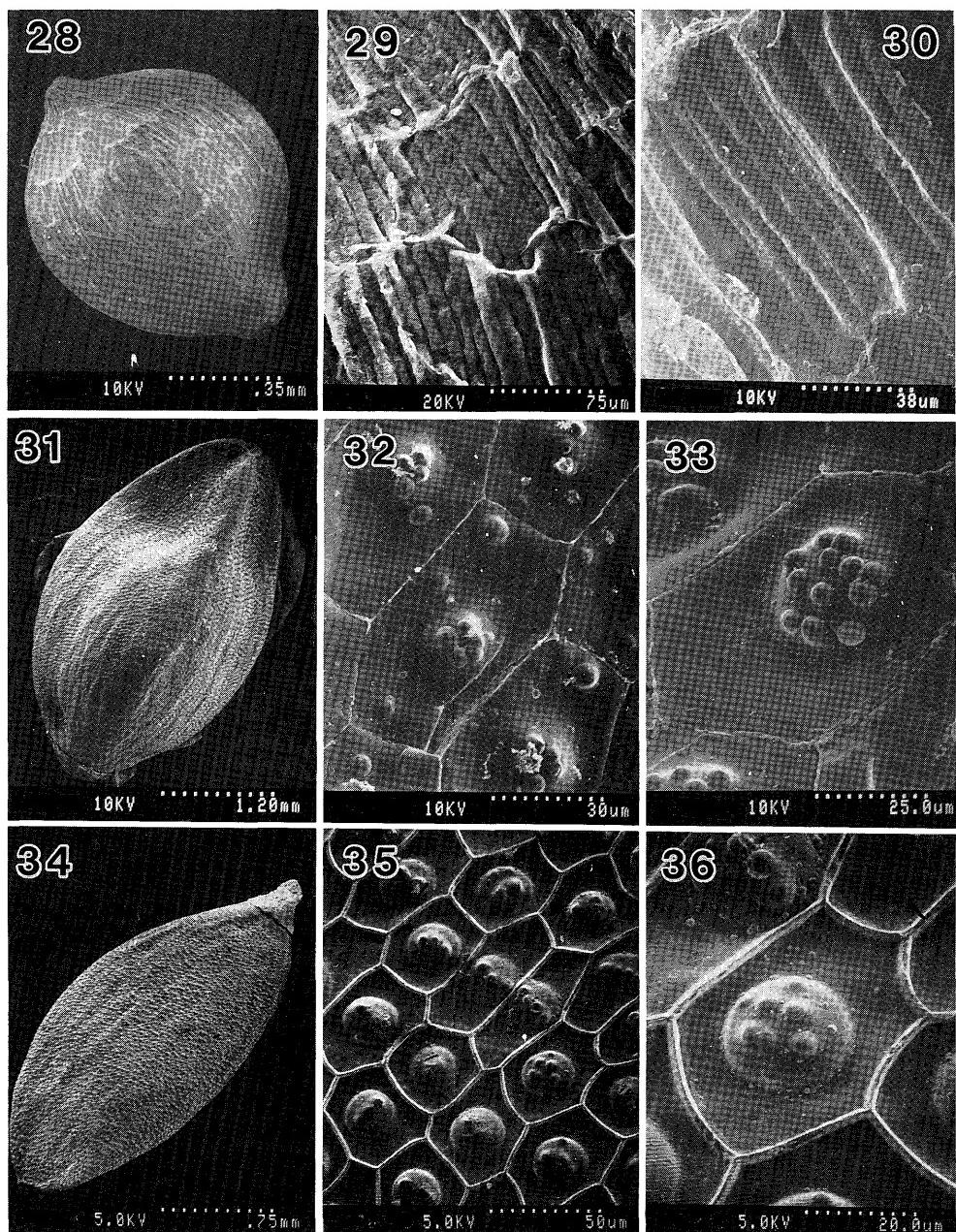
Figs. 19–27. Shape and microstructure of achenes in *Pycreus* (Cyperaceae) from China. 19–21. *P. pumilus*. 22–24. *P. sanguinolentus*. 25–27. *P. diaphanus*.

sent.

8. *Pycreus sanguinolentus* (Vahl) Nees (Figs. 22, 23, 24)

Achenes broadly ovoid or obovoid, two-sides convex with beak, dark brown, 1.10–

1.18 mm × 0.93–0.98 mm in size; achene sculpture reticulate-tuberculate cell lumens hexagonal or nearly hexagonal, anticlinal walls thin, undulate, internal tangential cell walls with one tuberculate protuberance in



Figs. 28–36. Shape and microstructure of achenes in *Pycreus* and *Gahnia* (Cyperaceae) from China.
28–30. *P. pseudolatospicatus*. 31–33. *G. tristis*. 34–36. *G. javanica*.

the center, protuberance smooth, smaller protuberance ca. 3–4 μm in diameter, satellites none.

9. *Pycreus diaphanus* (Schrad.) Tang & Wang (Figs. 25, 26, 27)

Achenes broadly ovoid, two-sides convex with short beak, light brown or brown, 0.86–0.94 mm \times 0.70–0.78 mm in size; sculpture reticulate, cell lumens lengthwise hexagonal or narrowly pentagonal, anticlinal

walls linear, straight, conspicuously convex, internal tangential cell walls are covered with densely granulate satellites.

10. *Pycreus pseudo-latespicatus* L.K.Dai (Figs. 28, 29, 30)

Achenes broadly obovoid, two-sides convex with beak, brownish, 0.95–1.03 mm × 0.73–0.80 mm in size; fruit surface has densely longitudinal striate thickenings and transverse ridges, cell lumens unclear.

11. *Gahnia tristis* Nees (Figs. 31, 32, 33)

Achenes oblong, trigonous, one of three sides flat, and others convex, beak absent, dark brown or black, 3.50–3.85 mm × 1.95–2.05 mm in size; reticulate-tuberculate type in sculpture, cell lumens hexagonal or nearly hexagonal, anticlinal walls thin, straight, internal tangential cell walls smooth, with one tuberculate protuberance. The protuberance ca. 13–16 µm in diameter, with 3–12 tuberculate satellites at the apex.

12. *Gahnia javanica* Moritz (Figs. 34, 35, 36)

Achenes narrowly ellipsoid, trigonous, one of three sides flat, others convex, beak absent, brownish or brown, 2.60–2.85 mm × 1.25–1.45 mm in size, reticulate-tuberculate type in sculpture; cell lumens hexagonal or narrowly hexagonal, anticlinal walls thick, straight, conspicuously convex, internal tangential cell walls smooth. There is one tuberculate protuberance in the center of cell lumens. The tuberculate protuberances are comparatively large ca. 20–25 µm in diameter with 2–8 tuberculate satellites at the apex.

13. *Gahnia bariensis* Benl (Figs. 37, 38, 39)

Achenes narrowly ellipsoid, trigonous, one side flat and others slightly convex, beak absent, brown, 2.50–2.75 mm × 1.10–1.25 mm in size, reticulate-tuberculate type in the sculpture; cell lumens tetra- or hexagonal, anticlinal walls thin, straight, internal tangential cell walls smooth, with 1–2 larger verrucate protuberances that have 3–10 tuberculate satellites on the apex. Protuberances ca. 22–25 µm in diameter

14. *Schoenus calostachyus* (R.Br) Poir (Figs. 40, 41, 42)

Achenes irregularly obovoid, beak a low boss, inconspicuous, trigonous, one side flat, others slightly convex, grey-brown, 2.50–2.75 mm × 1.10–1.45 mm in size. Fruit coat is covered with powderiness, cell shape unclear, fruit surface irregularly hexagonal or nearly ovoid tuberculate protuberance.

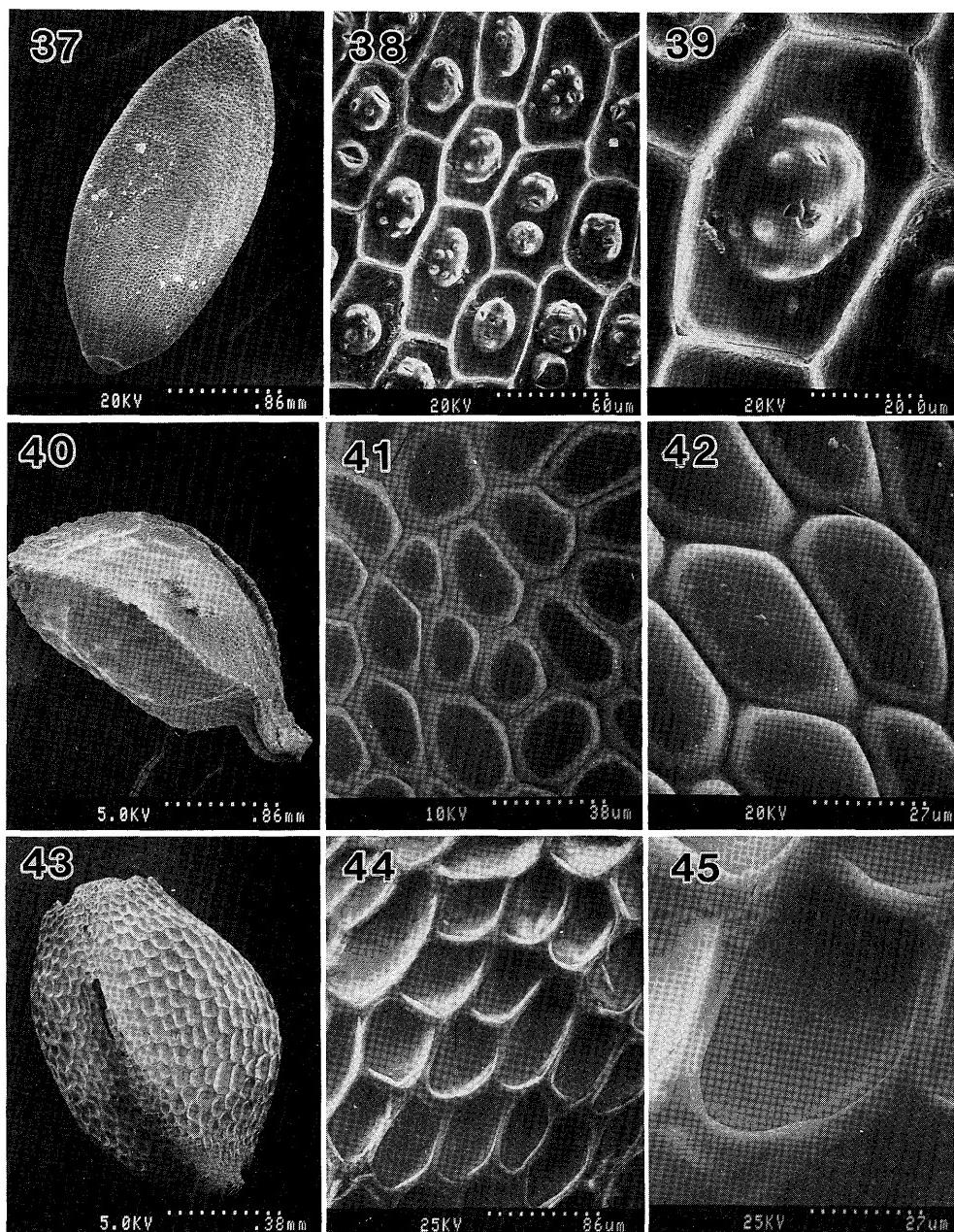
15. *Schoenus nudifructus* C.Chen (Figs. 43, 44, 45)

Achenes broadly ovoid or obovoid, trigonous, one of three sides flat, others rather convex, beak absent, brown, 1.10–1.25 mm × 0.70–0.85 mm in size, reticulate in the sculpture. Cell lumens of fruit surface hexagonal or irregularly hexagonal, anticlinal walls rather convex, internal tangential walls of cell smooth, slightly concaved in center.

Discussions

The microstructure of achenes such as the features of the anticlinal cell walls and cell lumens (silica bodies, e.g., *Carex*, *Cyperus*, *Eriophorum*, and *Scripus*) are useful for search at various taxonomic levels (Denton 1983, Francis 1991)

According to the characters of achenes mentioned above, the sculptures of achenes can be grouped into four types. Most of the achenes in *Pycreus* species belong to reticulate-tuberculate type suggesting that *Pycreus* is a natural group. It was noticed that there are some varieties in ornamentation and microstructure of achenes in different subgenera. For example, Subgen. Pyreus and Subgen. Zonatae (*P. pseudoletespicatus*) show different characters in ornamentation and microstructure; the former reveals the reticulate-tuberculate ornamentation which has a tuberculate protuberance in every lumen of the tangential walls, and the latter has a striate ornamentation such as longitudinal striate thickened and with several transverse ridges (Figs. 28–30). There is, how-



Figs. 37–45. Shape and microstructure of achenes in *Gahnia* and *Schoenus* (Cyperaceae) from China. 37–39. *G. bariensis*. 40–42. *S. calostachyus*. 43–45. *S. nudifructus*.

ever, no obvious differences in the epidermal ornamentation and microstructure of achenes between any two sections. For example, *Pycreus sulcinux* and *P. lijiangensis* are different in the shape of spikelet and the

numbers of stamen, the former belonging to Sect. *Pycreus* and the latter to Sect. *Globosi*. However, the achenes of this two species have not only the same ornamental structure, but also the similar configuration

of the anticlinal cell walls, the contour of the cell lumens and the number of tuberculate protuberance. Because of similar morphology of rhizome, inflorescence, spikelet and so on, *P. delavayi* and *P. unioloides* were placed in Sect. Lancei, but obvious differences in ornamentation and microstructure of achenes were observed in these two species.

Although there are some obvious differences in shape, color and size of achenes among the three genera, the classification of ornamentation types is not consistent with the taxonomical treatment in the three genera described.

In conclusion, the achenes of the three genera are diverse in the characters of ornamentation and micromorphology (e.g., the configuration of the anticlinal cell walls, the presence protuberance and the number of satellites), but consistent for species, and such characters can supply characteristics distinguish the genera at species level.

We are thankful to Professors Li Zhenyu and Liang Songyun of the Institute of Botany, Academia Sinica, Beijing who offer us the materials and various aid for this work. This research was supported by A Grant for Oversea Research from Ministry of Education 10041183.

Reference

- Denton M. F. 1983. Anatomical studies of the *Luzulae* group of *Cyperus* (Cyperaceae). *Syst. Bot.* **8**: 250–262.
- Francis J. M. 1991. A preliminary micromorphological analysis of *Eleocharis* (Cyperaceae) achenes for systematic potential. *Can. J. Bot.* **69**: 1533–1541.
- Liu J. Q. 1992. A comparative study on the microstructural features of achene surface to *Fimbristylis* Vahl. *J. of Fujian Nor. Univ. (Natural Sci.)* **8**(1): 75–82.
- 1993. A SEM study on the microstructural features of achene surface to *Rhynchospora* Vahl. and *Mariscus* Gaertn. in China. *J. of Fujian Nor. Univ. (Natural Sci.)* **9**(13): 80–90.
- and Huang J. H. 1993. Studies on the microstructural features of *Cyperus* achene surface under SEM and its taxonomic significance. *Acta Bot. Boreal-Occident. Sinica* **13**(4): 283–289.
- and Lin G.Y and Chen C. X. 1993. Studies on the micromorphology of achene surface *Scirpus* Linn. from Fujian. *Wuyi Sci.* **10**(C part): 34–43.
- , Lin G.Y and Huang J H. 1995. Effects of different treatments on microstructural feature of *Cyperus* achene surface under SEM. *Subtrop. Plant Res. Commun.* **24**(1): 4–9.
- Tan J. and Wang F. Z. 1961. Cyperaceae. In: Qian C. S. and Chen H. Y. (eds.), *Flora of China* **11**: 1–2. Science Press, Beijing.
- Tucker G. C. and Norton G. M. 1990. Achenes microstructure in *Eriophorum* (Cyperaceae): Taxonomic implications and paleobotanical applications. *Bull. Torrey Bot. Club.* **117**(3): 266–283.
- Appendix: Key to the genera and species of *Pycnecus*, *Gahnia* and *Schoenus* by achenes characters**
1. Achenes convex two-sided
 2. Achene surface Reticulate-tuberculate
 3. Achenes 0.57–0.96 mm in length
 4. Anticlinal walls thin, lumina concave along the margin *P. pumilus*
 4. Anticlinal walls thin or thick, lumina level along the margin
 5. Anticlinal walls thin, straight
 6. Tuberculate protuberance large (ca. 9–10 µm) *P. polystachyus*
 6. Tuberculate protuberance small (ca. 4–5 µm) *P. lijiangensis*
 5. Anticlinal walls thick or thin with undulate
 7. Tangential walls smooth... *P. delavayi*
 7. Tangential walls slightly convex, rough *P. globosus*
 3. Achenes 1.10–1.46 mm in length
 8. Anticlinal walls conspicuously convex, achenes oblong or obovoid
 9. Irregularly reticulate-tuberculate, anticlinal walls concave, tangential walls rough *P. unioloides*
 9. Anticlinal walls thin, straight... *P. sulcinox*
 8. Anticlinal walls conspicuously sinuous, achenes broadly obovoid
 - *P. sanguinolentus*
 2. Achenes surface reticulate or striate
 10. Achenes surface reticulate, tangential walls of achenes with dense granules *P. diaphanus*
 10. Achenes surface striate, tangential walls of achenes with striate thickenings
 - *P. pseudolatespicus*

1. Achenes trigonous
11. Achenes surface reticulate-tuberculate with satellites at the apex
12. Anticlinal walls of achenes thick and straight, conspicuously convex *G. javanica*
12. Anticlinal walls of achenes thin, slightly convex
13. Verruciform protuberance of achenes with 3–12 tuberculate satellites at the apex, lu

- mina with 1–3 tubercles *G. tristis*
13. Verruciform protuberance of achenes with 2–6 tuberculate satellites at the apex. lumina without tubercles *G. bariensis*
11. Achene surface reticulate or tuberrucate
14. Achene surface reticulate, lumina nearly hexagonal *S. nudifructus*
14. Achene surface densely tuberrucate
..... *S. calostachyus*

劉 剣秋^a, 林 蘇娟^b:中国産カヤツリグサ科カヤツリグサ属, クロガヤ属およびノグサ属の果実の形態

中国産カヤツリグサ科カヤツリグサ属の10種, クロガヤ属の3種およびノグサ属の2種, 合計15種類の果実を走査電子顕微鏡によって, 観察した。瘦果の形, 大きさ, くちばし状先端の有無などの形質が属レベルの分類の参考に値する。本研究では, クチクラと外周縁の表皮を除去した瘦果の表面模様を観察したところ, 15種のなかで, 4タイプが見られた: 1. 網目 - 結節状。瘦果の表面の垂層細胞壁は網目状となり, 単一の結節状の突起は

並層細胞壁の中央にある。2. 条紋状。瘦果の表面は条紋状模様であるが, 細胞の形がはっきりしない。3. 網目状。垂層細胞壁は網目状となり, 並層細胞壁に附属物がない。4. 結節状。瘦果の表面細胞は結節状である。以上の形質は各種に混じり合うので, 属間の区別ができないことが明らかになった。しかし, 種間の差異があることが見られ, 15種全ての種間特徴を上げることができた。

(^a中国福建師範大学生物工程学院,

^b立教大学理学部生命理学)